

IMPELLER PUMPS

[0000]

This application claims priority to Japanese patent application serial number 2002-303611, the contents of which are incorporated herein by reference.

[0001]

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to impeller pumps of a type known as Westco pumps, generative or friction pumps, cascade pumps and circumferential-flow pumps that have rotary impellers.

[0002]

Description of the Related Art

A known generative or friction pump 101 for pumping fuel is shown in FIGS. 10(A) and 10(B) and includes an impeller 102. The impeller 102 is disposed within a pump casing 106 and is rotatably driven by a motor 105 via a drive shaft 105a of the motor 105. Grooves 102a are defined in each of upper and lower surfaces of the impeller 102 and are arranged in the circumferential direction of the impeller 102. In order to minimize the outer diameter of the pump 101, a suction port 101a is defined in the pump casing 106, such that the fuel flows from the lower side of the impeller 102 into a first main flow channel 103a defined in the pump casing 106 in a direction perpendicular to the surface of the impeller 102. A second main flow channel 103b is defined in the pump casing 106 on the side opposite to the first main flow channel 103a. A plurality of communication holes 102b are defined in the impeller 102 and each of the communication holes 102b communicates between two of the grooves 102a that oppose to each other in the axial direction of the impeller 102 and defined in the upper and lower surfaces of the impeller 102, respectively. As a result, the fuel may flow uniformly into the first and second main flow channels 103a and 103b disposed on both sides of the impeller 102, so that the pumping efficiency may be improved. This type of known generative or friction fuel pump is disclosed in Japanese Laid-Open Patent Publication No. 5-18388.

[0003]

However, when the grooves 102a with the communication holes 102b are positioned to communicate with the suction hole 101a during the rotation of the impeller 102, the grooves

102a cannot produce circulation (swirl) of flow of the fuel. Therefore, it is not possible to start the pumping action immediately after the fuel has been drawn into the suction hole 101a. Due to this phenomenon, there still exists a problem that the pumping efficiency is degraded. In order to improve the pumping operation, the rotational speed of the impeller 102 may be increased. However, this may increase the amount of consumption of the electric power.

[0004]

SUMMARY OF THE INVENTION

It is accordingly an object of the present invention to teach impeller pumps that can improve the pumping efficiency.

[0005]

According to one aspect of the present teachings, impeller pumps for fluids are taught that include a rotary impeller and a first and second pump chambers defined on both sides of the impeller. A first inlet channel and a second inlet channel are defined in the pump housing. The first inlet channel communicates with one end of the first main flow channel and the second inlet channel communicates with one end of the second main flow channel, so that the fluid is drawn into the first pump chamber and the second pump chamber via the first inlet channel and the second inlet channel, respectively.

[0006]

Therefore, it is not necessary to provide communication holes in the impeller in order to communicate between the first pump chamber and the second pump chamber. The fluid may be pumped by the pumping actions of the impeller when the fluid reaches the start end of the first and second pump chambers via the first and second inlet channels, respectively. As a result, the pumping efficiency may be improved.

[0007]

According to another aspect of the present teachings, at least one of the first and second inlet channels is configured to improve the pumping efficiency by controlling the flow of the fluid. For example, the at least one of the first and second inlet channels may be configured not to directly open into the space defined in the pump housing for rotatably receiving the impeller. Alternatively, the direction(s) of the at least one of the first and second inlet channels may be determined to provide a smooth flow of the fluid, to intensify the swirls that may be produced

when the fluid flows into the corresponding pump chamber(s), or to provide a long flow path(s) along the corresponding main flow channel(s).

[0008]

According to another aspect of the present teachings, at least one of the first and second outlet channels also may be configured to improve the pumping efficiency by controlling the flow of the fluid. For example, the direction(s) of the at least one of the first and second outlet channels may be determined to provide a long flow path(s) along the corresponding main flow channel(s).

[0009]

According to another aspect of the present teachings, the flow of the fluid from the first outlet channel and the flow of the fluid from the second outlet channel converge at a convergence port defined in the pump housing.

[0010]

According to another aspect of the present teachings, the pump housing comprises a first pump housing member and a second pump housing member. The first inlet channel, the first main flow channel and the first outlet channel are defined in series in the first pump housing member, and the second inlet channel, the second main flow channel and the second outlet channel are defined in series in the second pump housing.

[0011]

According to another aspect of the present teachings, the impeller pump further includes a motor for rotating the impeller.

[0012]

BRIEF DESCRIPTION OF THE DRAWINGS

Additional objects, features and advantages of the present invention will be readily understood after reading the following detailed description together with the claims and the accompanying drawings, in which:

FIG. 1 is a vertical sectional view of a first representative impeller pump according to the present invention;

FIG. 2 is an enlarged vertical sectional view of a part of a pump housing of the first representative impeller pump;

FIG. 3 is a cross sectional view of a pump housing of a second representative impeller pump;

FIG. 4 is an enlarged vertical sectional view similar to FIG. 2 but showing a part of a pump housing of a third representative impeller pump;

FIG. 5(a) is an enlarged vertical sectional view of a part of a pump housing of a fourth representative impeller pump;

FIG. 5(b) is a schematic front view showing a modification of the fourth representative impeller pump;

FIG. 6(a) is an enlarged vertical sectional view similar to FIG. 4 but showing a part of a pump housing of a fifth representative impeller pump;

FIG. 6(b) is an enlarged vertical sectional view similar to FIG. 6(a) but showing a part of a pump housing of a modification of the fifth representative impeller pump;

FIG. 7(a) is a cross sectional view of a pump housing of a sixth representative impeller pump;

FIG. 7(b) is a side view of the pump housing of the sixth representative impeller pump;

FIG. 8 is a cross sectional view, with a part omitted, of a pump housing of a seventh representative impeller pump.

FIG. 9 is a cross sectional view, with a part omitted, of a pump housing of an eighth representative impeller pump.

FIG. 10(a) is a vertical sectional view of a known impeller pump; and

FIG. 10(b) is a cross sectional view taken along line X-X in FIG. 10.

[0013]

DETAILED DESCRIPTION OF THE INVENTION

In one embodiment of the present teachings, impeller pumps for fluids may include a rotary impeller and a pump housing. For example, the fluids may be fuels and the impeller pumps may be fuel pumps for supplying the fuels to internal combustion engines of automobiles. The pump housing defines a first main flow channel and a second main flow channel. The rotary impeller is disposed within a space defined in the pump housing and opposes to the first main flow channel and the second main flow channel, so that a first pump chamber and a second pump chamber are defined on both sides of the impeller. The rotary

impeller may have rows of grooves formed on both sides of the impeller and the grooves in each row are spaced equally from each other in the circumferential direction.

[0014]

A first inlet channel and a second inlet channel are defined in the pump housing. For example, the first and second inlet channels may be separate bores formed in the pump housing. The first inlet channel communicates with one end of the first main flow channel and the second inlet channel communicates with one end of the second main flow channel, so that the fluid is drawn into the first pump chamber and the second pump chamber via the first inlet channel and the second inlet channel, respectively.

[0015]

A first outlet channel and a second outlet channel are defined in the pump housing. The first outlet channel communicates with the other end of the first main flow channel and the second outlet channel communicates with the other end of the second main flow channel. Preferably, the pump housing comprises a first pump housing member and a second pump housing member. The first inlet channel, the first main flow channel and the first outlet channel may be defined in series in the first pump housing member. The second inlet channel, the second main flow channel and the second outlet channel may be defined in series in the second pump housing. The first and second outlet channels may converge at a discharge port that is defined in the pump housing and opposes to an outer periphery of the impeller in the radial direction.

[0016]

Because the fluid may be supplied into the first and second pump chambers via the first and second inlet channels, respectively, it is not necessary to provide communication holes in the impeller in order to communicate the fluid between the first and second pump chambers. Therefore, the fluid may be pumped by the pumping actions of the impeller as soon as the fluid reaches the start end of the first and second pump chambers via the first and second inlet channels. As a result, the pumping efficiency may be improved.

[0017]

In another embodiment of the present teachings, at least one of the first inlet channel and the second inlet channel has a longitudinal axis that is offset in the axial direction of the impeller from a central axis of the corresponding pump chamber(s), and the central axes of the

first pump chamber and the second pump chamber extend in the circumferential direction of the impeller.

[0018]

Therefore, swirls of flow of the fluid may be effectively produced when the fluid enters from the at least one of the first and second inlet channels into the corresponding pump chamber(s). As a result, the pumping efficiency can further improved.

[0019]

According to another embodiment of the present teachings, at least one of the first and second inlet channels is inclined relative to a plane that is perpendicular to the axial direction of the impeller. Therefore, the swirls of flow of the fluid can be intensified and the pumping efficiency can be further improved.

[0020]

According to another embodiment of the present teachings, the first and second inlet channels open to the outside via respective inlet openings, and the first and second outlet channels communicate with the terminal ends of the first and second main flow channels via respective communication openings. At least one of the inlet openings extends along an angular range (α) about a rotational axis of the impeller and the corresponding communication opening(s) extends along an angular range (β) about the rotational axis of the impeller. The angular range (α) and the angular range (β) at least partly overlap with each other. Therefore, the inlet opening(s) may be positioned away from the start end(s) of the corresponding main flow channel toward the communication openings. As a result, the length of the at least one of the first and second inlet channels becomes longer to further improve the pumping efficiency.

[0021]

According to another embodiment of the present teachings, each of the first and second main flow channels extend along a substantially arc shaped path, and at least one of the first and second inlet channels extends along a tangential direction with respect to the substantially arc shaped path of the corresponding main flow channel(s). Therefore, the fluid may smoothly enter the corresponding pump chamber(s) from the at least one of the first and second inlet channels without turbulence. As a result, the resistance against flow of the fluid may be reduced or minimized and the pumping efficiency may be improved.

[0022]

According to another embodiment of the present teachings, at least one of the first and second inlet channels extends along a direction that is inclined outwardly by an angle of (θ) relative to a tangential line (L1) with respect to the substantially arc shaped path of the corresponding main flow channel(s). Therefore, the length of the corresponding main flow channel(s) may become longer to further improve the pumping efficiency.

[0023]

Preferably, the angle of (θ) is defined by the tangential line (L1) and a central line (L2) of the at least one of the first and second inlet channels. The central line (L2) extends along a direction of a resultant vector (S1) from a first vector component (S2) and a second vector component (S3) of the flow velocity of the fluid at the start end of the corresponding main flow channel(s). The first vector component (S2) is oriented to extend along the tangential line (L1) and the second vector component (S3) is oriented in the radial direction of the impeller. With this arrangement, the swirls that may be produced at the start end(s) of the first main flow channel and/or the second main flow channel can be intensified to improve the pumping efficiency.

[0024]

According to another embodiment of the present teachings, at least one of the first and second outlet channels extends along a direction that is inclined outwardly by an angle of (γ) relative to a tangential line (L3) with respect to the substantially arc shaped path of the corresponding main flow channel(s). Therefore, the length of the corresponding main flow channel(s) becomes longer to further improve the pumping efficiency.

[0025]

Preferably, the angle of (γ) is defined by the tangential line (L3) and a central line (L4) of the at least one of the first and second outlet channels. The central line (L4) extends along a direction of a resultant vector (V1) from a first vector component (V2) and a second vector component (V3) of the flow velocity of the fluid at the terminal end(s) of corresponding main flow channel(s). The first vector component (V2) is oriented to extend along the tangential line (L3) and the second vector component (V3) is oriented in the radial direction of the impeller. With this arrangement, the fluid may smoothly flow out of the pump housing with minimum turbulence, so that the pumping efficiency can be further improved.

[0026]

In another embodiment of the present teachings, the impeller pumps further include a motor, e.g., an electric motor, for rotating the impeller. Therefore, the impeller pumps can be advantageously used as fuel pumps that are disposed within fuel tanks of automobiles.

[0027]

Each of the additional features and teachings disclosed above and below may be utilized separately or in conjunction with other features and teachings to provide improved impeller pumps and methods of using such impeller pumps. Representative examples of the present invention, which examples utilize many of these additional features and teachings both separately and in conjunction, will now be described in detail with reference to the attached drawings. This detailed description is merely intended to teach a person of skill in the art further details for practicing preferred aspects of the present teachings and is not intended to limit the scope of the invention. Only the claims define the scope of the claimed invention. Therefore, combinations of features and steps disclosed in the following detailed description may not be necessary to practice the invention in the broadest sense, and are instead taught merely to particularly describe representative examples of the invention. Moreover, various features of the representative examples and the dependent claims may be combined in ways that are not specifically enumerated in order to provide additional useful embodiments of the present teachings.

[0028]

Various representative embodiments will now be described with reference to FIGS. 1 to 7. Representative impeller pumps of these representative embodiments may be configured as generative or friction pumps and may be used as fuel pumps that are disposed within fuel tanks of vehicles, e.g., automobiles.

[0029]

(First Representative Embodiment)

Referring to FIGS. 1 and 2, a first representative impeller pump 1 is shown in a vertical sectional view and an enlarged view of a part of FIG. 1, respectively. The first representative impeller pump 1 may include a main casing 2. A first pump housing member 3 and a second pump housing member 4 are disposed within the main casing 2 and may be coupled together to form a pump housing. A recess 3e is defined in the first pump housing member 3 and opposes to the second pump housing member 4. An impeller 5 is rotatably disposed within the recess

3e. An electric motor 6 is disposed within the main casing 2 and has an output shaft 6a. The output shaft 6a extends through the first pump housing member 3 and is coupled to the impeller 5, so that the impeller 5 rotates as the motor 5 is driven. A plurality of grooves 5a are defined in each of upper and lower surfaces of the impeller 5 and are spaced equally from each other in the circumferential direction of the impeller 5 so as to form a circumferential groove row 5b. Each of the grooves 5a has a substantially semi-circular cross section and has a closed circumferential edge that defines an opening. Two adjacent grooves 5a of each groove row 5b may form a fin between each other.

[0030]

A first main flow channel 3a and a second main flow channel 4a are defined as recesses formed in the first pump housing member 3 and the second pump housing member 4 and are disposed to oppose to the impeller 5 from the upper side and the lower side, respectively. Each of the first and second main flow channels 3a and 4a has a substantially arc shaped configuration. Inlet channels 3b and 4b also are defined as recesses formed in the first pump housing member 3 and the second pump housing member 4, respectively. The inlet channel 3b communicates with a start end in the circumferential direction of the first main flow channel 3a and extends substantially radially outward from the first main flow channel 3a. The inlet channel 4b communicates with a start end in the circumferential direction of the second main flow channel 4a and extends substantially radially outward from the first main flow channel 4a. Here, the inlet channels 3b and 4b are defined independently of each other and do not communicate with each other. A terminal end of the first main flow channel 3a opposite to the start end thereof and a terminal end of the second main flow channel 4a opposite to the start end thereof communicate with outlet channels 3c and 4c, respectively. The outlet channels 3c and 4c also are defined as recesses formed in the first pump housing member 3 and the second pump housing member 4, respectively. The outlet channels 3c and 4c extend outward in the radial direction of the impeller 5 and converge at a discharge port 3d. The discharge port 3d is defined in the first pump housing member 3 and is disposed to directly oppose to the outer periphery of the impeller 5 in the radial direction of the impeller 5. The discharge port 3d communicates with an inner space 1a defined within the main casing 2. An upper cover 7 is fixedly fitted into the upper portion of the main casing 2 and has an outlet port 7a. Therefore, the fuel discharged from the discharge port 3d may flow through the inner space 1a around the

motor 6 and may then flow out of the impeller pump 1 via the outlet port 7a. The upper cover 7 rotatably supports one end of the output shaft 6a of the motor 6. The other end of the output shaft 6a is rotatably supported by the first pump housing member 3.

[0031]

The operation of the above first representative impeller pump 1 will now be described. As the motor 6 is driven, the impeller 5 coupled to the output shaft 6a of the motor 6 rotates. Then, the rows 5b of the grooves 5a defined in both upper and lower surfaces of the impeller 5a may cooperate with the first and second main flow channels 3a and 4b to perform pumping operations based on a known principle of generative or friction pumping action, so that the fuel may be drawn from the outside of the impeller pump 1 into the first and second main flow channels 3a and 4a via the inlet channels 3b and 4b, respectively. In this way, the first main flow channel 3a and the second main flow channel 4a may cooperate with the respective rows 5b of the grooves 5a to define a first pump chamber 1b and a second pump chamber 1c, respectively. The fuel drawn into the first and the second pump chambers 1b and 1c may flow along the circumferential lengths of the first and second main chambers 1b and 1c. The fuel may then flow into the discharge port 3d via the outlet channels 3c and 4c and may be discharged to the outside of the impeller pump 1 via the inner space 1a around the motor 6 and the outlet port 7a. The impeller 5 of the impeller pump 1 is different from the impeller of the known impeller pump (see FIG. 10), because the impeller 5 does not have any communication holes that communicate between two recesses 5a that oppose to each other in the axial direction of the impeller 5. Therefore, the swirl of flow of the fuel may be produced within the recesses 5a even at positions adjacent to the terminal ends of the inlet channels 3b and 4b (at the start ends of the first and second main flow channels 3a and 4a) in order to provide the pumping actions.

[0032]

Second to eighth representative embodiments will now be described with reference to FIGS. 3 to 9. These representative embodiments are modifications of the first representative embodiment. Therefore, in FIGS. 3 to 9, like members are given the same reference numerals as the first representative embodiment and explanation of these elements will not be necessary.

[0033]

(Second Representative Embodiment)

Referring to FIG. 3, there is shown a cross sectional view of a second representative impeller pump, which is different from the first representative impeller pump 1 only in the configuration of a first pump housing member 13 that corresponds to the first pump housing member 3 of the first representative impeller pump 1. As shown in FIG. 3, a first main flow channel 13a and an inlet channel 13b are defined in the first pump housing member 13. The inlet channel 13b communicates with the first main flow channel 13a and extends substantially tangentially from the start end of the first main flow channel 13a that is configured to have a substantially arc-shaped configuration similar to the first main flow channel 3a of the first representative embodiment. The inlet channel 13b opens to the outside via an inlet opening 13e. [0034]

Because the inlet channel 13b is arranged to extend substantially tangentially from the first main flow channel 13a, the fuel that enters the inlet channel 13b via the inlet opening 13e flows into the first main flow channel 13a without producing any turbulence. Therefore, resistance against the flow of the fluid that is drawn into the first main flow channel 13a may be reduced or minimized. As a result, the pumping efficiency may be further improved. [0035]

Although not shown in the drawings, an inlet channel communicating with a second main flow channel also may be configured to extend substantially tangentially from the start end of the second main flow channel. [0036]

(Third Representative Embodiment)

Referring to FIG. 4, there is shown an enlarged sectional view of a pump housing of a third representative impeller pump. FIG. 4 corresponds to FIG. 2 of the first representative embodiment. The third representative impeller pump is different from the first representative impeller pump 1 only in the configurations of a first pump housing member 23 and a second pump housing member 24 that correspond to the first pump housing member 3 and the second pump housing member 4 of the first representative impeller pump 1, respectively. As shown in FIG. 4, the first and second pump housing members 23 and 24 have inlet channels 23b and 24c that are configured as bores that extend substantially in a horizontal direction, i.e., within a plane that is perpendicular to the rotational axis of the impeller 5, respectively. Thus, the inlet channels 23b and 24c do not directly open into the recess 3e that is defined in the first pump

housing member 23 for receiving the impeller 5. Therefore, a minimum clearance 23c can be ensured between the first pump housing members 23 and the upper surface of the impeller 5 in a position adjacent to the inlet channel 23b. Similarly, a minimum clearance 24c can be ensured between the second pump housing member 24 and the lower surface of the impeller 5 in a position adjacent to the inlet channel 24b.

[0037]

Due to the minimum clearances 23c and 24c, the fuel drawn into the inlet channels 23b and 24b may be prevented from causing leakage to a radial space 25 that is defined between the outer circumferential surface of the impeller 5 and a wall of the recess 3e opposing to the impeller 5 in the radial direction. Therefore, the pumping efficiency may be further improved. The inlet channels 23b and 24b may have various cross sectional configurations, e.g., circular configurations, elliptical configurations and rectangular configurations as will be hereinafter described in connection with fourth and fifth representative embodiments. The fourth and fifth representative embodiments relate to specific cross sectional configurations and the arrangement of the inlet channels, respectively. In other respect, the fourth and fifth representative embodiments are the same as the third representative embodiment.

[0038]

(Fourth Representative Embodiment)

Referring to FIG. 5(a), there is shown an enlarged sectional view of a pump housing of the fourth representative impeller pump. The fourth representative impeller pump includes a first pump housing member 33 and a second housing member 34 that corresponds to the first pump housing member 23 and the second pump housing member 24 of the third representative embodiment, respectively. An inlet channel 33b is defined in the first pump housing member 33 and an inlet channel 34b is defined in the second pump housing member 34. Each of the inlet channels 33b and 34b has a substantially circular cross section and has a central axis that is offset from the central axis of a corresponding first pump chamber 31a or second pump chamber 31b by a distance C. The first and second pump chambers 31a and 31b are defined between a first pump channel 33a formed in the first pump housing member 33 and the grooves 5a on the upper side of the impeller 5 and between a second pump channel 34a formed in the second pump housing member 34 and the grooves 5a on the lower side of the impeller 5. In the representative embodiment shown in FIG. 5(a), each of the first and second pump channels 33a

and the grooves 5a has a substantially semi-circular configuration. Therefore, the central axes of the first and second pump chambers 31a and 31b are positioned substantially within boundary planes between the first and second pump housing members 33 and 34 and the impeller 5.

[0039]

Because the central axes of the inlet channels 33a and 33b are offset from the central axes of the respective first and second pump chambers 31a and 31b by the distance C, the flow of the fuel that enters from the inlet channels 33a and 33b into the first and second pump chambers 31a and 31b, respectively, may reliably produce swirls as indicated by arrows in FIG. 5(a). As a result, the pumping efficiency can be further improved.

[0040]

Although the inlet channels 33a and 33b extend in the horizontal direction, i.e., parallel to planes within which the central axes of the first and second pump chambers 31a and 31b extend, respectively, in the third representative impeller pump shown in FIG. 5(a), the inlet channels 33b and 34b may be inclined relative to the respective planes of the central axes of the first and second pump chambers 31a and 31b as shown in FIG. 5(b). With this arrangement, the flow of the fuel that enters from the inlet channels 33a and 33b into the first and second pump chambers 31a and 31b, respectively, may further reliably produce swirls as indicated by arrows in FIG. 5(b). As a result, the pumping efficiency may be further improved.

[0041]

(Fifth Representative Embodiment)

Referring to FIG. 6(a), there is shown an enlarged sectional view of a part of a pump housing of the fifth representative impeller pump. The fifth representative impeller pump includes a first pump housing member 43 and a second housing member 44 that correspond to the first pump housing member 23 and the second pump housing member 24 of the third representative embodiment, respectively. Each of an inlet channel 43b defined in the first pump housing member 43 and an inlet channel 44b defined in the second pump housing member 44 has a substantially elliptical cross section that has a major axis extending in the horizontal direction. Also in this representative embodiment, each of the inlet channels 43b and 44b has a central axis that is offset from the central axis of a corresponding first pump channel 41a or second pump channel 42a by a predetermined distance. Here, the first pump

channel 41a is defined by the recesses 5a on the upper side of the impeller 5 and a first main flow channel 43a formed in the first housing member 43. The second pump channel 42a is defined by the recesses 5a on the lower side of the impeller 5 and a second main channel 44a formed in the second pump housing member 44.

[0042]

In the fifth representative impeller pumps, the cross sectional configurations of the inlet channels 43b and 44b are elongated or flattened (in comparison with the circular cross sectional configuration) in the horizontal direction or the directions parallel to planes within which central axes of the first and second pump chambers 41a and 42a extend. Therefore, the offset distance of the inlet channels 43b and 44b from the central axes of the respective first and second pump chambers 41a and 42a can be increased and the swirls can be produced for a broader range in the horizontal direction. As a result, the swirls of the flow of the fuel may be intensified and such intensified swirls may be produced at the start ends of the first and second pump channels 43a and 44b (or the first and second pump chambers 41a and 42a) immediately after the fuel flows into these pump channels. Therefore, the pumping efficiency may be further improved. In addition, transmission of pulsations of flow of the fuel (that may be produced as the impeller 5 rotates for performing the pumping actions) to the outside via the inlet channels may be reduced or minimized, so that pump noises may be reduced or minimized.

[0043]

Referring to FIG. 6(b), there is shown an enlarged sectional view of a pump housing of a modification of the fifth representative impeller pump. Each of an inlet channel 45b defined in the first pump housing member 43 and an inlet channel 46b defined in the second pump housing member 44 has a substantially rectangular cross sectional configuration that has long sides extending in the horizontal direction. The short sides of the inlet channels 45b and 46b are rounded. Also in this representative embodiment, each of the inlet channels 45a and 46b has a central axis that is offset from the central axis of the corresponding first pump chamber 41a and the second pump chamber 42a by a predetermined distance.

[0044]

Also in this modification, the cross sectional configurations of the inlet channels 45b and 46b are elongated or flattened in the horizontal direction or the directions parallel to planes

of the central axes of the first and second pump chambers 41a and 42a. Therefore, the same operations and advantages as the fifth representative embodiment can be attained.

[0045]

In addition, also in the above fifth representative embodiment and its modification, the inlet channels 43b and 44b (inlet channels 45b and 46b) may be inclined relative to the horizontal direction, i.e., planes within which the central axes of the first and second pump channels extend as explained in connection with the modification of the fourth representative embodiment shown in FIG. 5(b).

[0046]

(Sixth Representative Embodiment)

A sixth representative embodiment will now be described with reference to FIGS. 7(a) and 7(b). Referring to FIG. 7(a), there is shown a cross sectional view of a pump housing of a sixth representative impeller pump. The sixth representative impeller pump also is a modification of the third representative impeller pump and is different from the third representative impeller pump only in the configurations of inlet channels.

[0047]

The sixth representative impeller pump includes a first pump housing member 54 and a second housing member 53 that corresponds to the first pump housing member 23 and the second pump housing member 24 of the third representative embodiment, respectively. Each of an inlet channel 54b defined in the first pump housing member 54 and an inlet channel 53b defined in the second pump housing member 53 has a substantially rectangular cross section elongated in the horizontal direction and has a central axis that is offset from the central axis of a corresponding pump channel by a predetermined distance.

[0048]

As shown in FIG. 7(a), one end of the inlet channel 53b communicates with a start end of a second main flow channel 53a and the other end of the inlet channel 53b opens to the outside via an inlet opening 53e formed in the main casing 2. The inlet opening 53e has width that extends by a range of an angle α about the drive shaft 6a of the motor 6, i.e., the rotational axis of the impeller 5. On the other hand, an outlet channel 53c communicates with a terminal end of the second main flow channel 53a via a substantially circular opening as viewed in FIG. 7(a), which opening has a width that extends by a range of an angle β about

the drive shaft 6a of the motor 6. As shown in FIG. 7(a), the range of the angle α is set to overlap with the range of the angle β .

[0049]

With this arrangement, the flow path constituted by the inlet channel 53b and the second main flow channel 53a may have a length that is greater than the same flow path according to the design, in which the range of the angle α is set not to overlap with the range of the angle β . Thus, the length of the inlet channel 53b may become longer as the position of the inlet opening 53e is set to be farther away from the start end of the second main flow channel 53a in the clockwise direction as viewed in FIG. 7(a).

[0050]

Because the flow path constituted by the inlet channel 53b may have a greater length, the pumping efficiency can be further improved.

[0051]

Although not shown in the drawings, an angular range of an inlet opening of the inlet channel 54b also is set to overlap with an angular range of an opening of an outlet channel at a terminal end of a first pump channel.

[0052]

(Seventh Representative Embodiment)

A seventh representative embodiment will now be described with reference to FIG. 8. Referring to FIG. 8, there is shown a cross sectional view of a part of a pump housing of a seventh representative impeller pump. The seventh representative impeller pump also is a modification of the third representative impeller pump and is different from the third representative impeller pump only in the configurations of inlet channels.

[0053]

Referring to FIG. 8, a second main flow channel 63a and an inlet channel 63b are defined in a second pump housing member 63. The second main flow channel 63a, the inlet channel 63b and the second pump housing member 63 correspond to the second main flow channel 4a, the inlet channel 24b and the second pump housing member 24 of the third representative impeller pump, respectively (see FIG. 4).

[0054]

As shown in FIG. 8, the inlet channel 63b is inclined outward of the second pump housing member 24 by an angle θ ($0^\circ < \theta < 90^\circ$) relative to a tangential line L1 that is drawn from an arc that defines the central line extending along the circumferential direction of the second main flow channel 63a.

[0055]

With this arrangement, the start end of the second main flow channel 63a can be positioned on the side in the clockwise direction than the position in the arrangement where the inlet channel extends in the radial direction of the impeller. Therefore, the second main flow channel 63a may have a longer length, so that the pumping efficiency can be improved. Preferably, a line L2 that defines the angle θ and corresponds to the central line of the inlet channel 63b extends along a direction of arrow S1 shown in FIG. 8. Here, the arrow S1 indicates a resultant vector from a main vector component S2 and a swirl vector component S3 of the flow velocity of the fuel at the start end of the main flow channel 63a. The main vector component S2 is oriented toward the tangential direction and the swirl vector component S3 is oriented in the radial direction. With this arrangement, the intensity of swirls may be further increased, so that the pumping efficiency may be further improved.

[0056]

Although not shown in FIG. 8a, an inlet channel communicating with a first main flow channel also may be configured in the same manner as the inlet channel 63b of the second pump housing member 53 described above.

[0057]

(Eighth Representative Embodiment)

An eighth representative embodiment will now be described with reference to FIG. 9. Referring to FIG. 9, there is shown a cross sectional view of a part of a pump housing of an eighth representative impeller pump. The eighth representative impeller pump is a modification of the first representative impeller pump and is different from the first representative impeller pump only in the configurations of outlet channels.

[0058]

Referring to FIG. 9, a second main flow channel 73a and an outlet channel 73c are defined in a second pump housing member 73. The second main flow channel 73a, the outlet channel 73c and the second pump housing member 73 correspond to the second main flow

channel 4a, the outlet channel 4c and the second pump housing member 4 of the first representative impeller pump, respectively.

[0059]

As shown in FIG. 9, the outlet channel 73c is inclined outward of the second pump housing member 73 by an angle γ ($0^\circ > \gamma > 90^\circ$) relative to a tangential line L3 that is drawn from an arc that defines the central line extending in the circumferential direction of the second main flow channel 73a.

[0060]

With this arrangement, the terminal end of the second main flow channel 73a can be positioned in the counterclockwise direction than the position in the arrangement where the outlet channel extends in the radial direction of the impeller. Therefore, the second main flow channel 73a may have a longer length, so that the pumping efficiency can be improved. Preferably, a line L4 that defines the angle γ and corresponds to the central line of the inlet channel 63b extends along a direction of an arrow V1 shown in FIG. 9. Here, the arrow V1 indicates a resultant vector from a main vector component V2 and a swirl vector component V3 of the flow velocity of the fuel at the terminal end of the main flow channel 73a. The main vector component V2 is oriented toward the tangential direction and the swirl vector component V3 is oriented in the radial direction. With this arrangement, the fuel may flow out of the outlet channel 73c with reduced turbulence, so that the pumping efficiency can be further improved.

[0061]

Although not shown in FIG. 9, an outlet channel communicating with a first main flow channel also may be configured in the same manner as the outlet channel 73c of the second pump housing member 73 described above. In addition, the arrangement of the outlet channel of this eighth representative impeller pump may be incorporated in combination with the arrangement of the inlet channels described in connection with the second to seventh representative embodiments.